

CLAIMS

1. A process for producing methane and/or high purity hydrogen, which comprises:

5 (a) anaerobically digesting organic materials by the action of bacteria and/or enzymes contained therein to produce a mixed gas stream containing methane, carbon dioxide and trace impurities including hydrogen sulfide, nitrogen and oxygen, wherein the mixed gas stream may also contain small quantities of water;

10 (b) optionally, removing at least a portion of any water contained in the mixed gas stream;

(c) compressing the optionally condensed, mixed gas stream; and

(d) (i) producing a methane product stream by removing hydrogen sulfide and/or carbon dioxide from the compressed, mixed gas stream; and/or

15 (ii) producing a high purity hydrogen product stream by generating hydrogen-rich gas from the compressed, mixed gas stream, and then by selectively removing hydrogen from the hydrogen-rich gas.

2. The process for producing methane and/or high purity hydrogen of claim 1, wherein the process is dedicated to the production of methane gas.

20 3. The process for producing methane and/or high purity hydrogen of claim 1, wherein the process is dedicated to the production of high purity hydrogen gas.

25 4. The process for producing methane and/or high purity hydrogen of claim 1, wherein the process serves to produce methane gas and high purity hydrogen gas.

5. The process for producing methane and/or high purity hydrogen of claims 2 or 4, wherein an absorbent selected from the group of activated charcoal, zinc oxide, and mixtures thereof, is used to remove hydrogen sulfide from the compressed, mixed gas stream.

30 6. The process for producing methane and/or high purity hydrogen of claims 2 or 4, wherein at least one selective membrane or film is used to remove carbon dioxide from the compressed, mixed gas stream, and wherein the selective

membrane or film is selected from the group of cellulose acetate, polysulfone and polyimide membranes and films and membranes made from fluorinated polymers.

7. The process for producing methane and/or high purity hydrogen of claims 3 or 4, wherein the hydrogen-rich gas is generated by first reacting steam with the compressed, mixed gas stream in the presence of a catalyst to form a gas containing, as principal components, hydrogen, carbon dioxide and carbon monoxide, and then by reacting steam with the carbon monoxide in the formed gas to produce carbon dioxide and additional hydrogen.

8. The process for producing methane and/or high purity hydrogen of claim 7, wherein one or more hydrogen-permeable membranes are used to selectively remove hydrogen from the hydrogen-rich gas.

9. The process for producing methane and/or high purity hydrogen of claims 3 or 4, wherein a steam reformer and a high temperature shift/membrane reactor are used to produce the high purity hydrogen product stream, wherein the high temperature shift/membrane reactor comprises, in one unit, a reactor that generates hydrogen and at least one hydrogen-permeable membrane that extracts hydrogen.

10. A self-contained and streamlined process for producing methane and/or high purity hydrogen from anaerobically digested organic materials, which comprises:

(a) anaerobically digesting organic materials by the action of bacteria and/or enzymes contained therein to produce a mixed gas stream containing methane, carbon dioxide and trace impurities including hydrogen sulfide, nitrogen and oxygen, wherein the mixed gas stream may also contain small quantities of water;

(b) optionally, directing at least a portion of the mixed gas stream to means for removing at least a portion of any water contained therein;

(c) directing portions of the optionally condensed, mixed gas stream to one or more gas-driven engines for fueling same, wherein the one or more gas-driven engines power a generator and optionally a compressor, and wherein the generator produces electrical energy for powering a hydrogen generation and removal system and/or a mixed gas purification device, and optionally the compressor;

(d) directing remaining portions of the optionally condensed, mixed gas stream to the compressor for compressing the gas stream; and

(e) directing the compressed, mixed gas stream to:

(i) the mixed gas purification device, which serves to remove hydrogen sulfide and/or carbon dioxide from the compressed, mixed gas stream to produce a methane product stream; and/or

(ii) the hydrogen generation and removal system, which comprises means for generating hydrogen-rich gas from the compressed, mixed gas stream, and means for selectively removing hydrogen from the hydrogen-rich gas, to produce a high purity hydrogen product stream.

11. A self-contained and streamlined process for producing methane and/or high purity hydrogen from anaerobically digested organic materials, which comprises:

(a) anaerobically digesting organic materials by the action of bacteria and/or enzymes contained therein to produce a mixed gas stream containing, among other things, methane, carbon dioxide and trace impurities including hydrogen sulfide, nitrogen and oxygen, wherein the mixed gas stream may also contain small quantities of water;

(b) optionally, directing at least a portion of the mixed gas stream to means for removing at least a portion of any water contained therein;

(c) directing portions of the optionally condensed, mixed gas stream to gas-driven engines that power:

(i) a generator, wherein the generator produces electrical energy for powering a hydrogen generation and removal system and/or a mixed gas purification device;

(ii) a first compressor;

(iii) one or more mixed gas-fired reforming furnaces;

(iv) one or more steam boilers; and

(v) optionally, a second compressor,

wherein the mixed gas stream serves to fuel the gas-driven engines;

(d) directing remaining portions of the optionally condensed, mixed gas stream to the first compressor for compressing the gas stream; and

(e) directing the compressed, mixed gas stream to:

(i) the mixed gas purification device, which serves to remove hydrogen sulfide and/or carbon dioxide from the compressed mixed gas stream to produce a methane product stream; and/or

(ii) the hydrogen generation and removal system, which comprises means for generating a hydrogen-rich gas from the compressed mixed gas stream, and means for selectively removing hydrogen from the hydrogen-rich gas to produce a high purity hydrogen product stream,

wherein, when the compressed, mixed gas stream is directed to the mixed gas purification device for removing hydrogen sulfide and/or carbon dioxide, the resulting purified, mixed gas stream is then directed to the second compressor for further compressing the gas stream prior to directing the gas stream into a natural gas pipeline and/or storage receptacles, and

wherein, when the compressed, mixed gas stream is directed to the hydrogen generation and removal system, the resulting high purity hydrogen product stream is directed to one or more hydrogen fueled devices and/or to the second compressor for further compressing the high purity hydrogen product stream prior to storing same.

12. A self-contained and streamlined methane and/or high purity hydrogen generation system, comprising:

(a) an anaerobic digester for anaerobically digesting organic materials by the action of bacteria and/or enzymes contained therein to produce a mixed gas stream containing methane, carbon dioxide and trace impurities including hydrogen sulfide, nitrogen and oxygen;

(b) at least one compressor in fluid communication with the anaerobic digester and in further fluid communication with a hydrogen generation and removal system and/or a mixed gas purification device;

(c) at least one mixed gas-driven generator in fluid communication with the anaerobic digester and in electrical communication with the hydrogen generation and removal system and/or the mixed gas purification device, and optionally, in further electrical communication with the compressor(s); and

(d) (i) the mixed gas purification device, which serves to remove hydrogen sulfide and/or carbon dioxide from the mixed gas stream to produce a methane product stream, wherein the mixed gas purification device is in fluid communication with the compressor and is in electrical communication with the generator; and/or

(ii) the hydrogen generation and removal system, which comprises means for generating a hydrogen-rich gas from the compressed, mixed gas stream, and means for selectively removing hydrogen from the hydrogen-rich gas to produce a high purity hydrogen product stream, wherein the hydrogen generation and removal system has an operating pressure, and is in fluid communication with the compressor and is in electrical communication with the generator.

13. The self-contained and streamlined methane and/or high purity hydrogen generation system of claim 12, wherein the system is dedicated to the production of methane gas and produces from about 40 to about 2,400 standard liters per minute of methane gas at pressures ranging from about 1.82 to about 2.86 megapascals, wherein the methane gas has a purity level of greater than 90%.

14. The self-contained and streamlined methane and/or high purity hydrogen generation system of claim 12, wherein the system is dedicated to the production of hydrogen gas and produces from about 40 to about 2,400 standard liters per minute of hydrogen gas at pressures ranging from about 100 to about 450 kilopascals, wherein the hydrogen gas has a purity level of greater than 99.99999%.

15. The self-contained and streamlined methane and/or high purity hydrogen generation system of claim 12, wherein the system produces both methane gas and high purity hydrogen gas.

16. The self-contained and streamlined methane and/or high purity hydrogen generation system of claims 13 or 15, wherein the at least one compressor compresses the mixed gas stream from the digester to a pressure exceeding the operating pressure of the mixed gas purification device.

17. The self-contained and streamlined methane and/or high purity hydrogen generation system of claims 14 or 15, wherein the at least one compressor compresses the mixed gas stream from the digester to a pressure exceeding the operating pressure of the hydrogen generation and removal system.

18. The self-contained and streamlined methane and/or high purity hydrogen generation system of claim 17, wherein the at least one compressor compresses the mixed gas stream from the digester to a pressure of greater than or equal to 2.17 megapascals.

5 19. The self-contained and streamlined methane and/or high purity hydrogen generation system of claim 18, wherein the at least one compressor compresses the mixed gas stream to a pressure of greater than or equal to 2.86 megapascals.

10 20. The self-contained and streamlined methane and/or high purity hydrogen generation system of claims 13 or 15, wherein the mixed gas purification device comprises an absorbent selected from the group of activated charcoal, zinc oxide and mixtures thereof, which serves to remove hydrogen sulfide from the compressed, mixed gas stream.

15 21. The self-contained and streamlined methane and/or high purity hydrogen generation system of claims 13 or 15, wherein the mixed gas purification device comprises at least one selective membrane or film, which serves to remove carbon dioxide from the compressed, mixed gas stream, wherein the selective membrane or film is selected from the group of cellulose acetate, polysulfone and polyimide membranes and films and membranes made from fluorinated polymers.

20 22. The self-contained and streamlined methane and/or high purity hydrogen generation system of claims 14 or 15, wherein the means for generating a hydrogen-rich gas from the compressed, mixed gas stream comprises a steam reformer and a high temperature shift reactor.

25 23. The self-contained and streamlined methane and/or high purity hydrogen generation system of claim 22, wherein the means for generating a hydrogen-rich gas further comprises means for removing hydrogen sulfide from the compressed, mixed gas stream entering the hydrogen generation and removal system.

30 24. The self-contained and streamlined methane and/or high purity hydrogen generation system of claims 14 or 15, wherein the means for selectively removing hydrogen from the hydrogen-rich gas comprises one or more hydrogen-permeable membranes.

25. The self-contained and streamlined methane and/or high purity hydrogen generation system of claims 14 or 15, wherein the hydrogen generation and removal system comprises a steam reformer and a high temperature shift/membrane reactor, wherein the high temperature shift/membrane reactor
5 comprises, in one unit, a reactor that generates hydrogen and at least one hydrogen-permeable membrane that extracts hydrogen.

26. The self-contained and streamlined methane and/or high purity hydrogen generation system of claim 25, wherein the high temperature shift/membrane reactor comprises: a chamber; an inlet port for introducing the
10 compressed, mixed gas stream into the chamber; a plurality of hydrogen-permeable membranes in the form of tubes having an outer surface in fluid communication with the compressed, mixed gas stream, and an inner surface in fluid communication with a hydrogen product stream that passes through the tubes housed within the chamber; a catalyst located within the chamber for facilitating an exothermic water-
15 gas shift reaction; a first outlet port for removing the hydrogen product stream; a second outlet port for removing a waste gas stream; and optionally, cooling means for withdrawing thermal energy from the chamber.

27. A self-contained and streamlined methane and/or high purity hydrogen generation system, which comprises:

20 (a) an anaerobic digester for anaerobically digesting organic materials by the action of bacteria and/or enzymes contained therein to produce a mixed gas stream containing methane, carbon dioxide and trace impurities including hydrogen sulfide, nitrogen and oxygen, wherein the mixed gas stream may also contain small quantities of water;

25 (b) first and second mixed gas-driven compressors in fluid communication with the anaerobic digester and in further fluid communication with a hydrogen generation and removal system having an operating pressure, wherein the first mixed gas-driven compressor compresses the mixed gas stream from the digester to a pressure exceeding the operating pressure of the hydrogen generation and removal system, and wherein the
30 second mixed gas-driven compressor compresses a high purity hydrogen product stream from the hydrogen generation and removal system to a pressure of greater than or equal to 20.8 megapascals;

(c) the hydrogen generation and removal system, which comprises a steam reformer and a high temperature shift/membrane reactor, wherein the hydrogen generation and removal system generates a hydrogen-rich gas from the compressed, mixed gas stream exiting the first mixed gas-driven compressor, and selectively removes hydrogen from the generated hydrogen-rich gas to produce a high purity hydrogen product stream;

(d) a mixed gas-driven generator in fluid communication with the anaerobic digester and in electrical communication with the hydrogen generation and removal system for powering same;

(e) optionally, a condenser in fluid communication with the anaerobic digester for removing at least a portion of any water contained in the mixed gas stream produced by the digester;

(f) means for directing the high purity hydrogen product stream exiting the hydrogen generation and removal system to low-pressure hydrogen fueled devices; and

(g) means for directing the high purity hydrogen product stream exiting the second compressor to one or more high pressure storage receptacles.

28. A self-contained and streamlined methane and/or high purity hydrogen generation system, which comprises:

(a) an anaerobic digester for anaerobically digesting organic materials by the action of bacteria and/or enzymes contained therein to produce a mixed gas stream containing methane, carbon dioxide and trace impurities including hydrogen sulfide, nitrogen and oxygen, wherein the mixed gas stream may also contain small quantities of water;

(b) first and second mixed gas-driven compressors in fluid communication with the anaerobic digester and in further fluid communication with a mixed gas purification device having an operating pressure, wherein the first mixed gas-driven compressor compresses the mixed gas stream from the digester to a pressure exceeding the operating pressure of the mixed gas purification device, and wherein the second mixed gas-driven compressor compresses a methane product stream from the mixed gas purification device to a pressure of greater than or equal to 20.8 megapascals;

(c) the mixed gas purification device, which serves to remove hydrogen sulfide and/or carbon dioxide from the mixed gas stream exiting the first mixed gas-driven compressor to produce a methane gas product stream;

5 (d) a mixed gas-driven generator in fluid communication with the anaerobic digester and in electrical communication with the mixed gas purification device for powering same;

(e) optionally, a condenser in fluid communication with the anaerobic digester for removing at least a portion of any water contained in the mixed gas stream produced by the digester; and

10 (f) means for directing the methane gas product stream exiting the second compressor to a bottling station and/or to a natural gas pipeline.